RECENT CHANGES OF CH_4 SINCE 2005 from FTIR observations and GEOS-CHEM simulation

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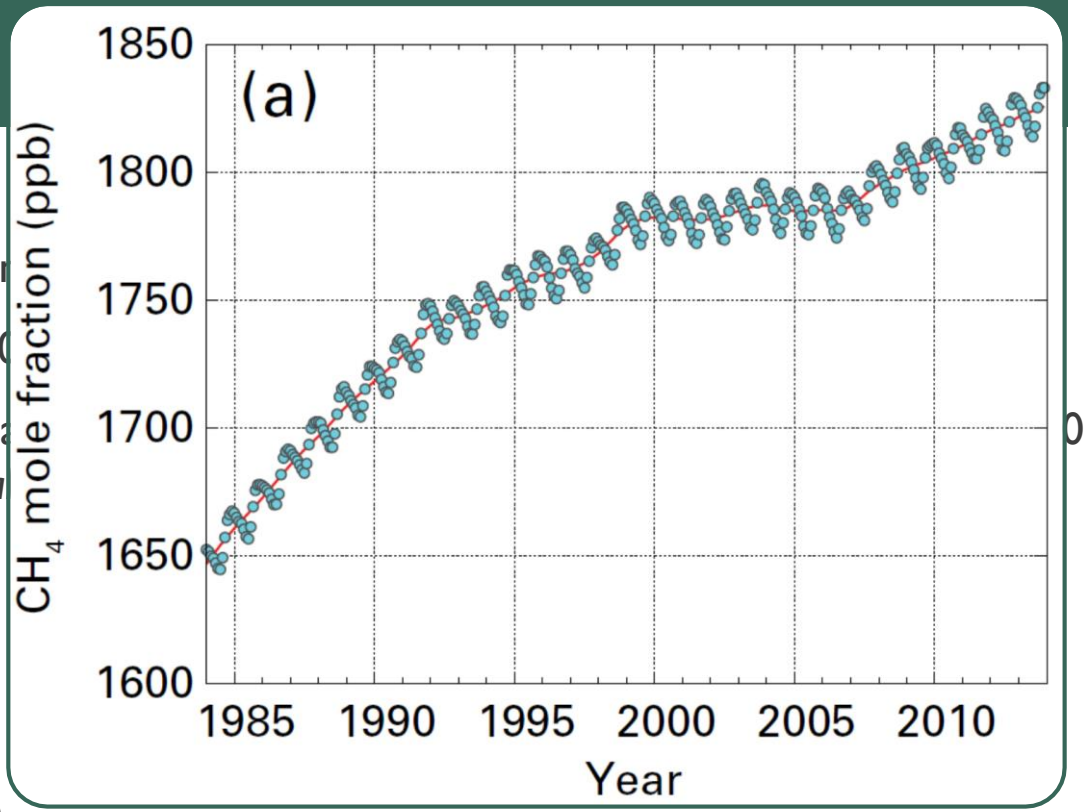
Methane changes

- Second anthropogenic greenhouse gas - GWP_{100} = 28 (IPCC-AR5)
- 1824 ppb : new high of +260% wrt pre-industrial levels (1750)
- ~1/5 of the increase in radiative forcing by human-linked greenhouse gases since 1750 is due to methane [*Nisbet et al.*, 2014]
- Non monotonic behaviour
- Last 25 years…
  - Increase in the 90s
  - 2000-2005/2006 : stable
  - The need "For a proper closure of the methane budget and the development of realistic future climate scenarios, methane emissions during this stabilization period should be understood and precisely quantified" *Pison et al., 2013*
  - From 2005/2006 : new increase → Why ?

Methane changes



WMO Bulletin n°10, 2014

- Second anthropogenic greer
- 1824 ppb : new high of +26(
- ~1/5 of the increase in radia 0 is due to methane [*Nisbet et a*
- Non monotonic behaviour
- Last 25 years…
  - Increase in the 90s
  - 2000-2005/2006 : stable
  - The need "For a proper closure of the methane budget and the development of realistic future climate scenarios methane emissions during this stabilization period should be understood and precisely quantified" *Pison et al., 2013*
  - From 2005/2006 : new increase → Why ? → Source attribution ?

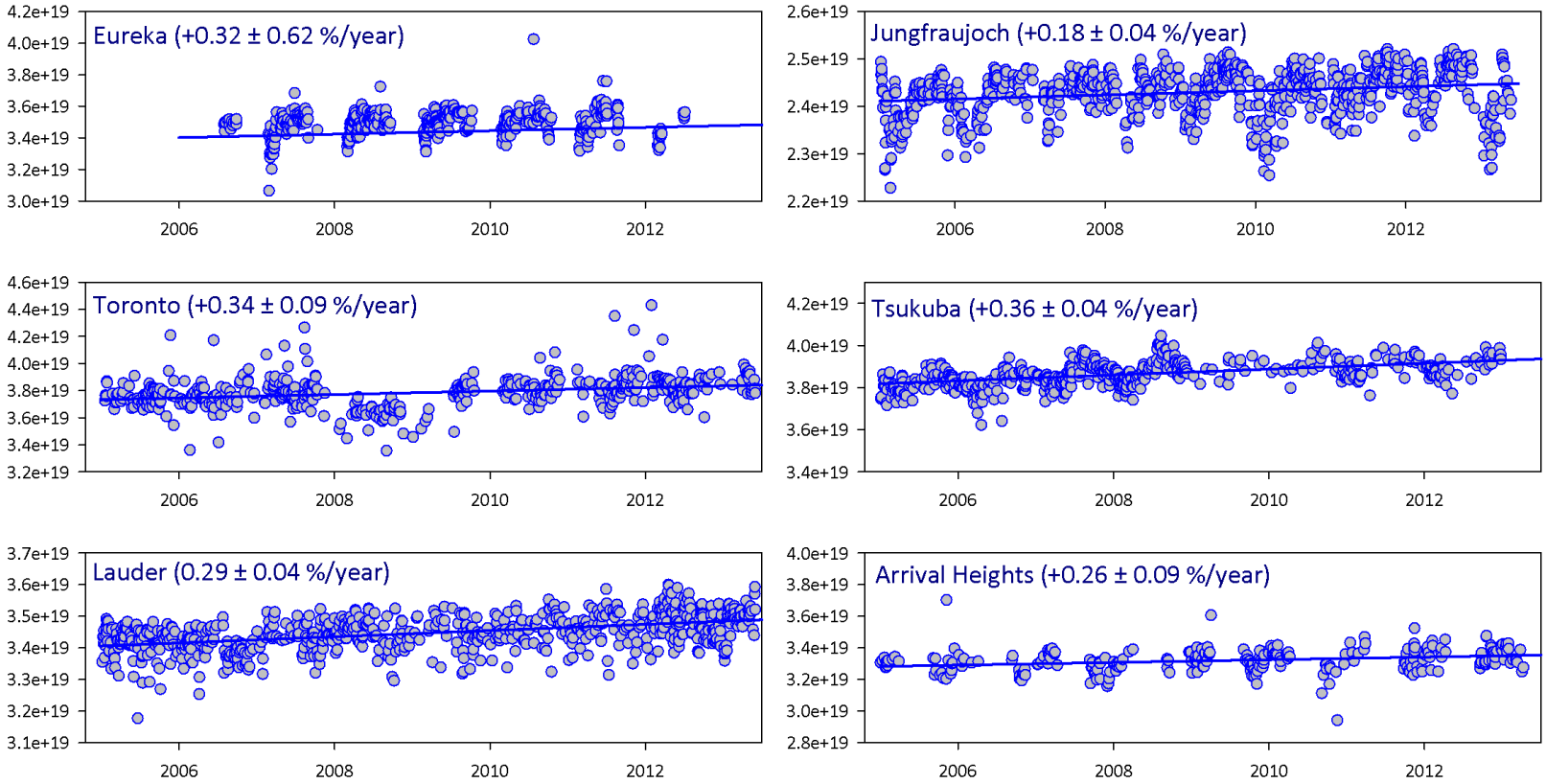
NDACC Sites

[1] Eureka (80 °N, 86 °W)
[2] Jungfraujoch (46 °N, 8 °E)
[3] Toronto (44 °N, 79 °W)

[4] Tsukuba (36 °N, 140 °E)
[5] Lauder (45 °S, 169 °E)
[6] Arrival Heights (77 °S, 166 °E)

FTIR Observations - Total Columns

Daily Mean Methane Total Columns in molecules/cm²



CH_4 global increase from WMO/GAW global greenhouse gas monitoring network : 0.33%

Source attribution ?

GEOS-CHEM tagged simulation

- ✓ GEOS-CHEM MODEL V9-02
- ✓ CHEMICAL TRANSPORT MODEL
- ✓ 2X2.5 & 47 vertical levels
- ✓ Time step : 3 hours
- ✓ GEOS5 (2005-2013/05)
- ✓ GFED3
- ✓ OH_v5-07-08
- ✓ EDGAR v4.2 (2004-2008)
- ✓ K. Wecht et al., 2014
- ✓ Each tracer represents the contribution of each source to the simulated total column of methane

Tracers
1- Total
2- Gas and oil
3- Coal
4- Livestock
5- Waste management
6- Biofuels
7- Rice cultures
8- Biomass burning
9- Wetlands
10- Other natural
11- Other anthropogenic
12- Soil absorption

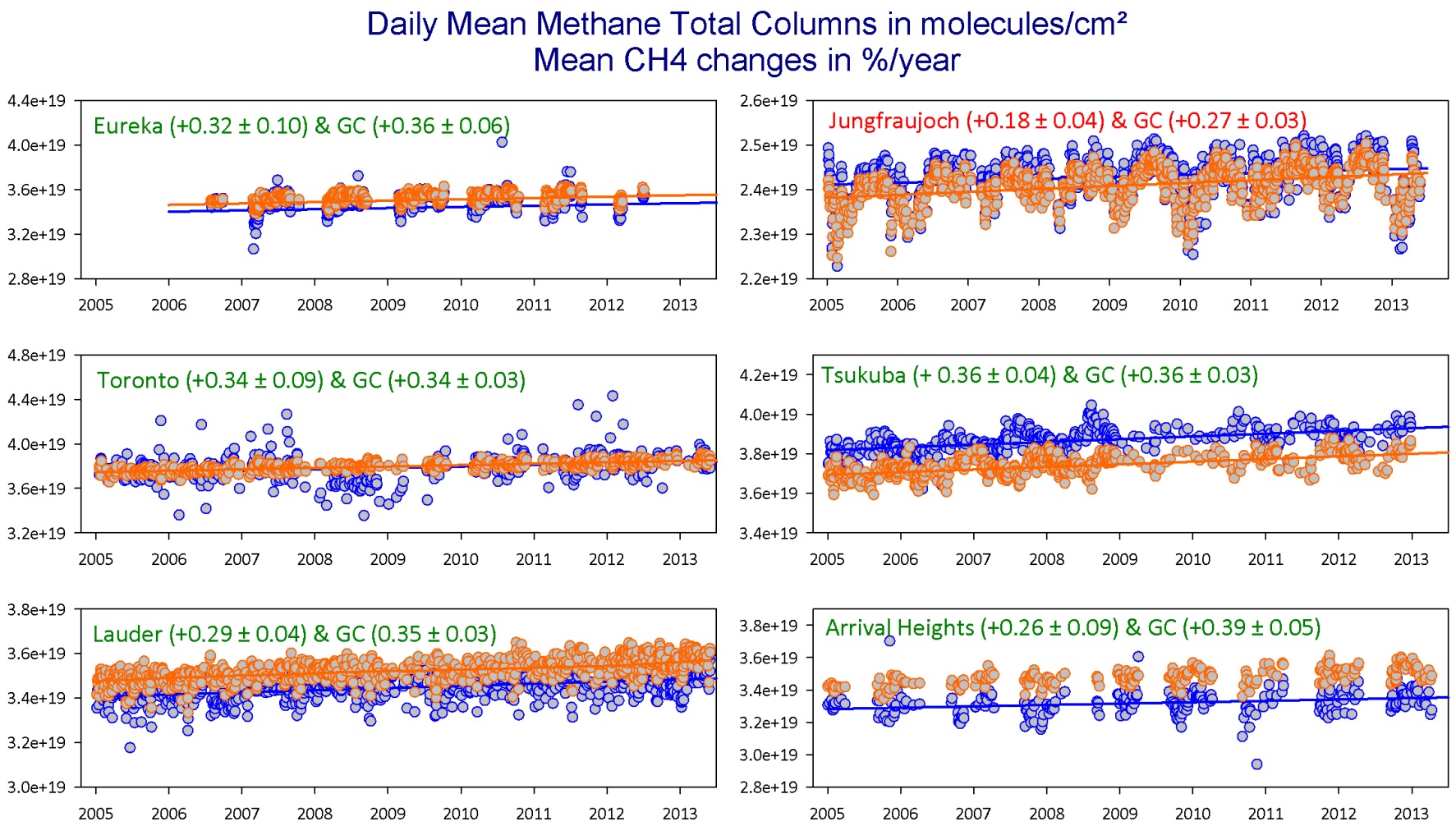
GEOS-CHEM Data Processing

- Nearest-neighbour interpolation to match ground-based instrument coordinates
- Conservative regridding scheme to the grid used in the FTIR retrieval
  - Specific to each station
- Smoothing of GEOS-CHEM data by the respective averaging kernels
- Changes calculation with a bootstrap resampling method
  - Linear fit + Fourier series (Gardiner et al., 2008)
  - Mean annual change (in %/year)
- Comparison only for days when observation is available

FTIR Observations vs GEOS-CHEM

Total Column

FTIR Observations vs. GEOS-CHEM Simulation Total Columns



GEOS-CHEM known issues

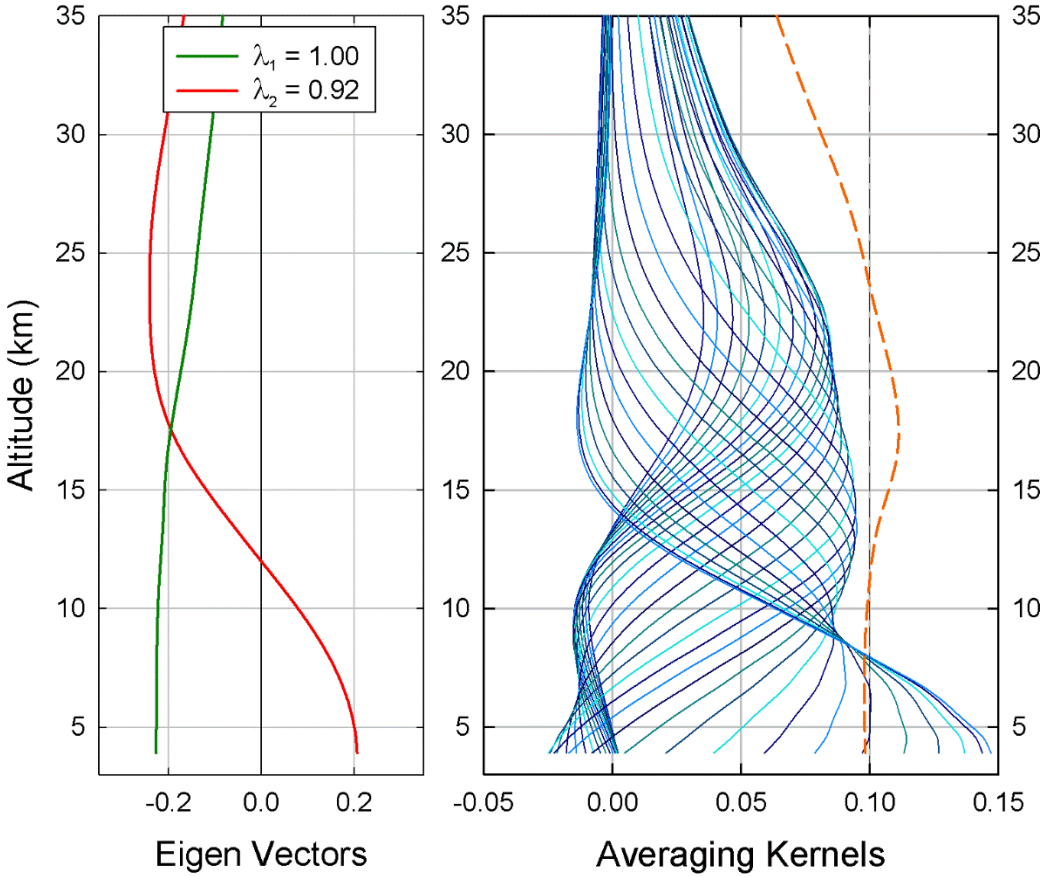
- EDGAR emission inventory
  - Spatial patterns
  - Increase in Chinese CH_4 emissions from coal after 2002 not supported by surface aircraft or satellite observations
  - Best inventory available
- Simplistic stratosphere (first order-loss)

- Best version available so far
- How good is the GEOS-CHEM simulation vertically ?

FTIR Observations
Information Content

DOFS = ~2.2 - Information content allows us to retrieve two partial columns

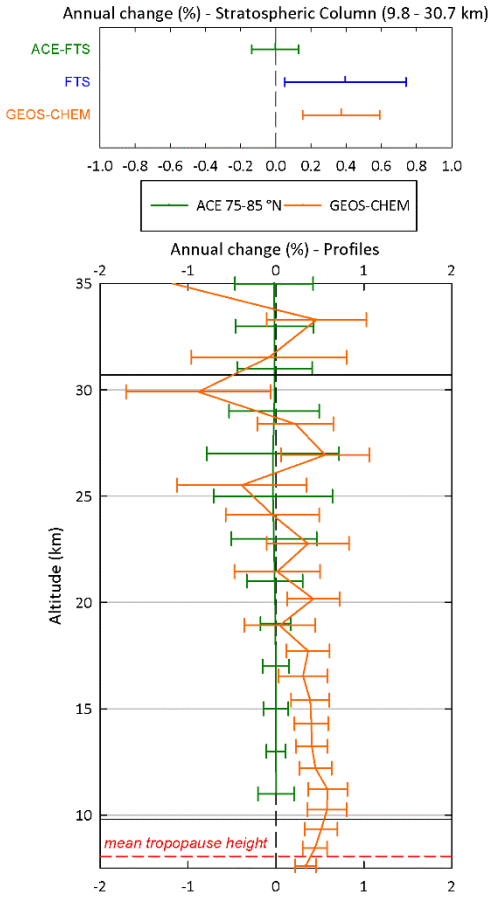
A tropospheric and a stratospheric one



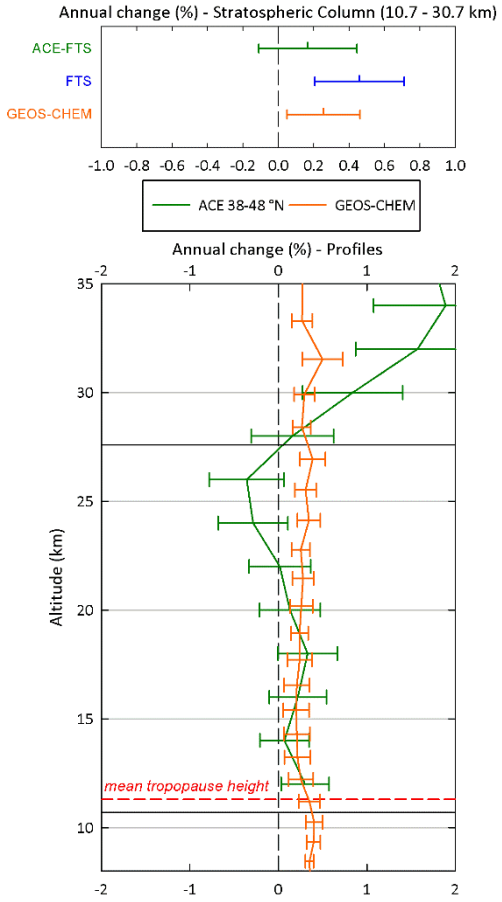
FTIR Observations vs GEOS-CHEM

Stratospheric Column

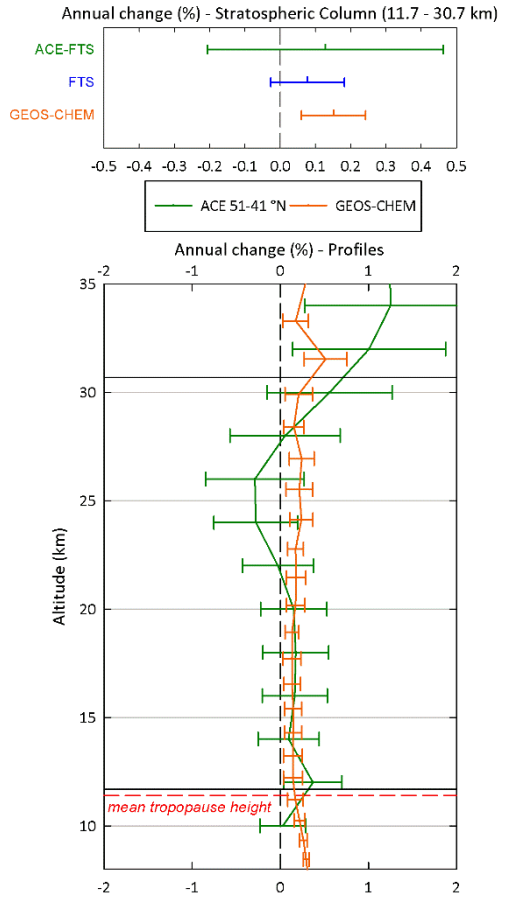
Eureka



Toronto



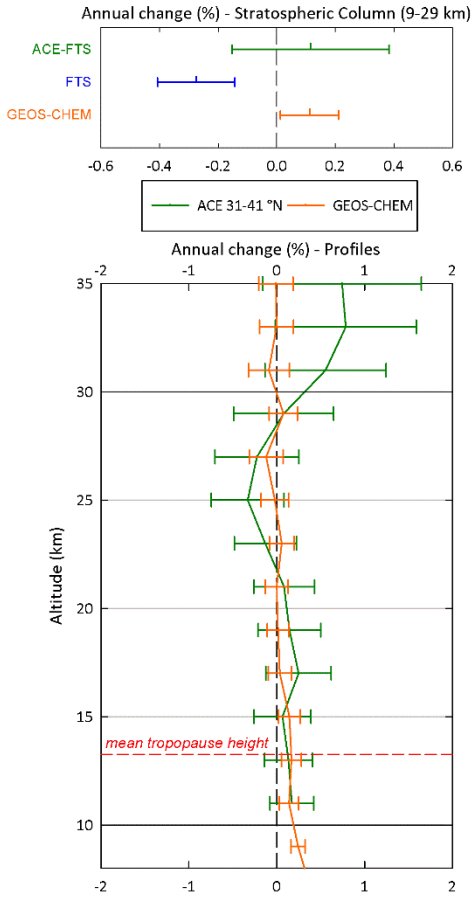
Jungfraujoch



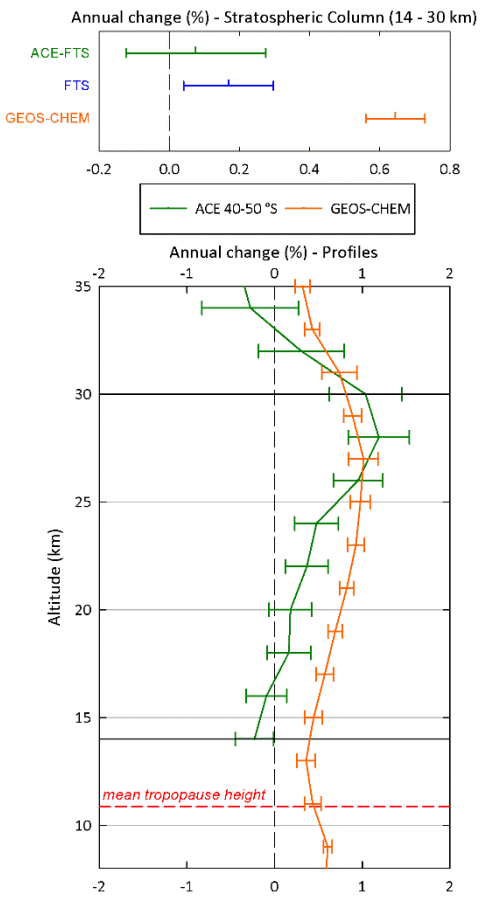
FTIR vs GEOS-CHEM
Stratospheric Methane
Mean Annual Changes in %

FTIR Observations, ACE-FTS occultations and the GEOS-CHEM simulation are statistically in agreement

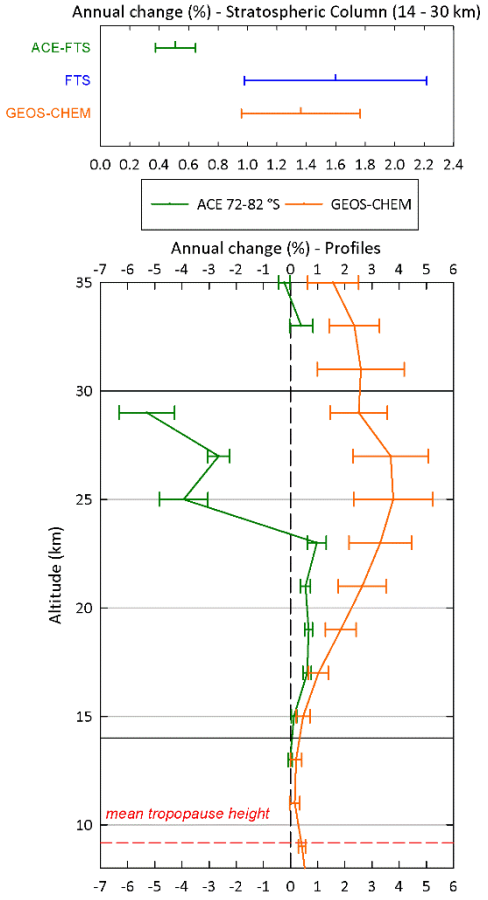
Tsukuba



Lauder



Arrival Heights



FTIR vs GEOS-CHEM
Stratospheric Methane
Mean Annual Changes in %

TSU - GC and FTS are not in agreement

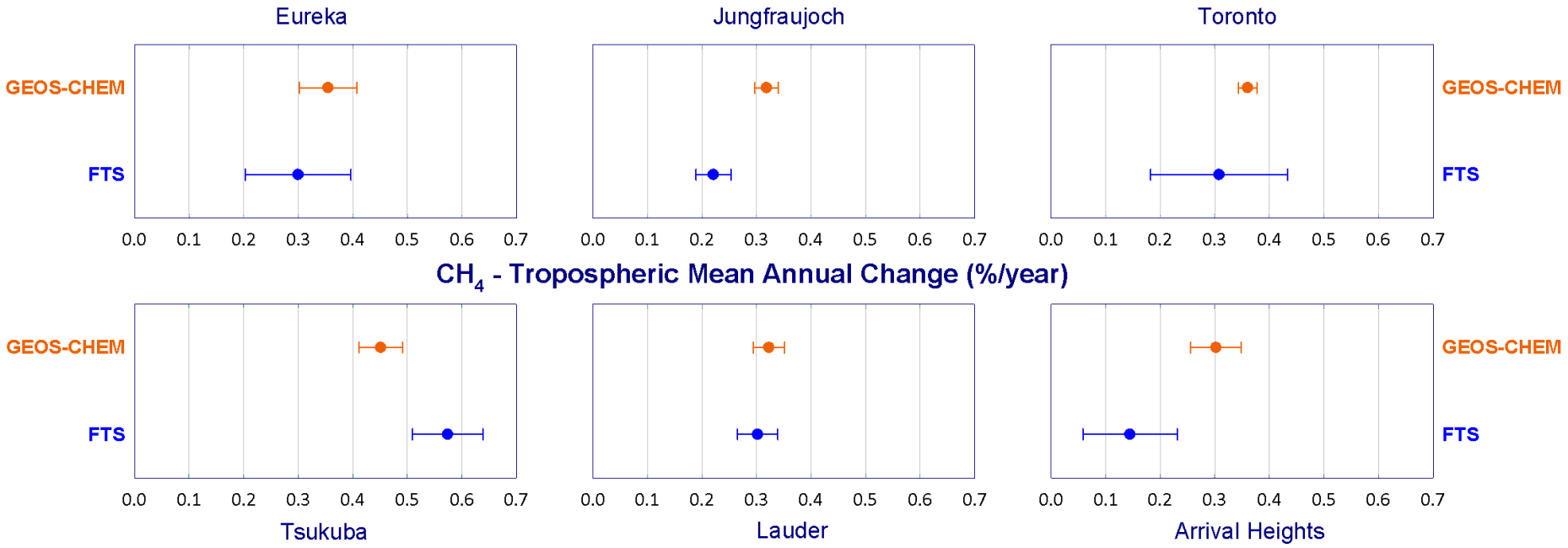
LAU - GC overestimates measurements

AHTS - ACE 10° band + polar vortex

FTIR Observations vs GEOS-CHEM

Tropospheric Column

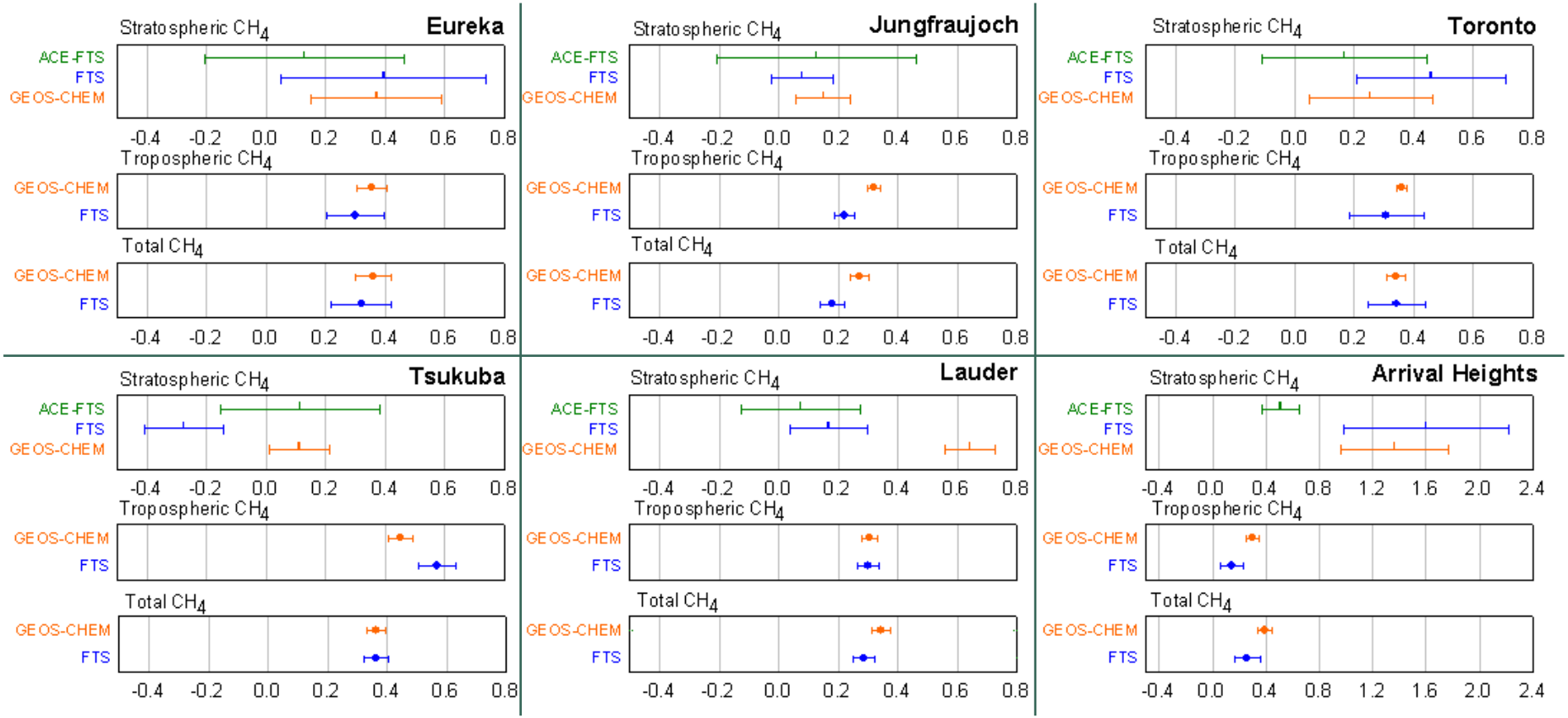
FTIR Observations vs GEOS-CHEM Simulation
Tropospheric methane



GEOS-CHEM tends to overestimate the tropospheric change but agrees within error bars for Eureka, Toronto and Lauder

Jungfraujoch : high altitude site (3.58 km) problem with vertial gradient of GC CH_4
Arrival heights : Polar Vortex issue ?

CH_4 changes - summary



CH_4 total column changes are in the same order of magnitude than the tropospheric one as observed by FTS and simulated by GEOS-CHEM whereas stratospheric CH_4 show different type of regime from one station to another.

What does the taggued simulation tell us about the methane changes ?

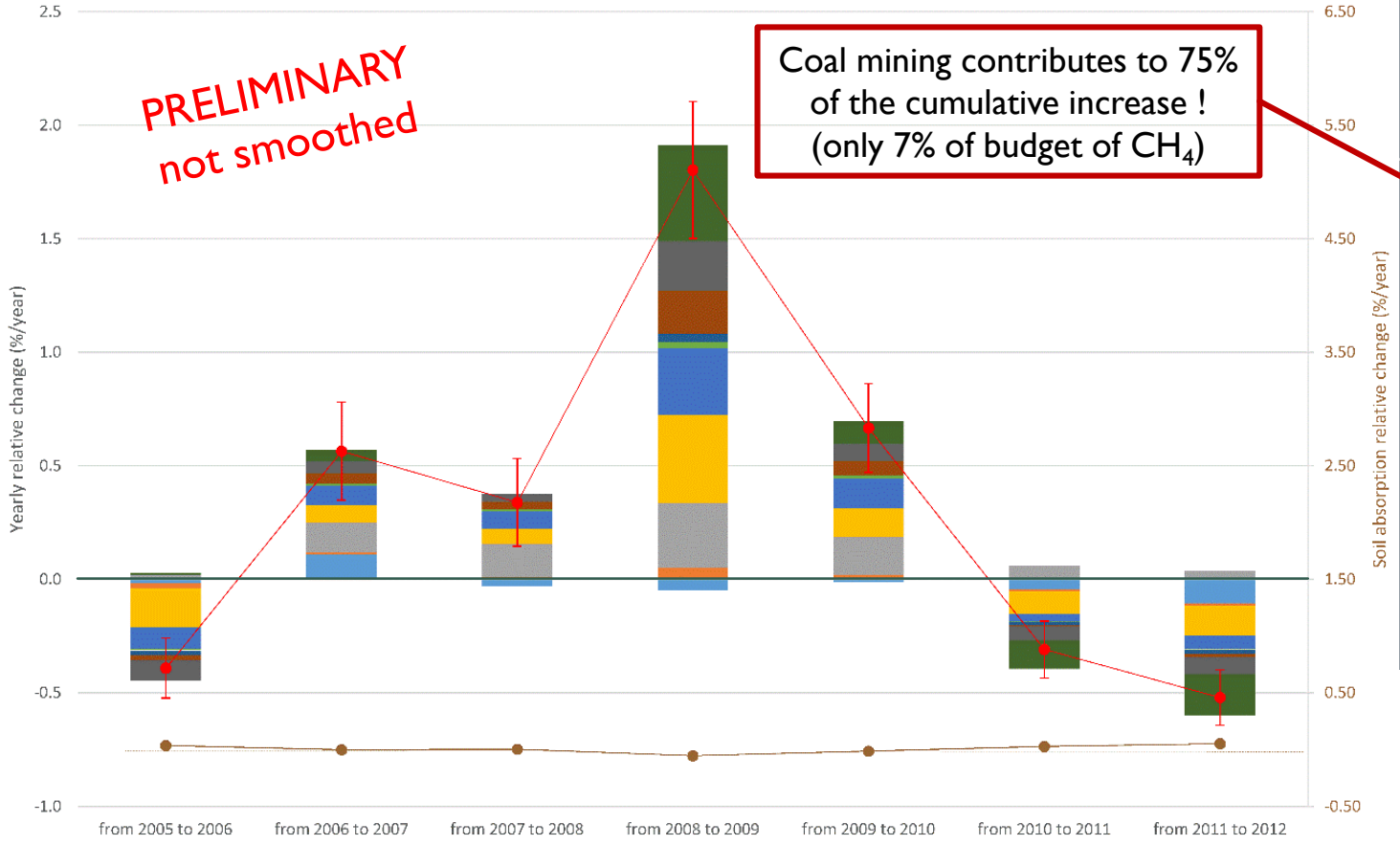
GEOS-CHEM - Tracer Analysis
Tropospheric CH_4 - Jungfraujoch

Yearly relative changes from one year to another to illustrate how each tracer contributes to the total CH_4 increase simulated by GEOS-CHEM

GEOS-CHEM - Tracer Analysis
Tropospheric CH_4 - Jungfraujoch

PRELIMINARY
not smoothed

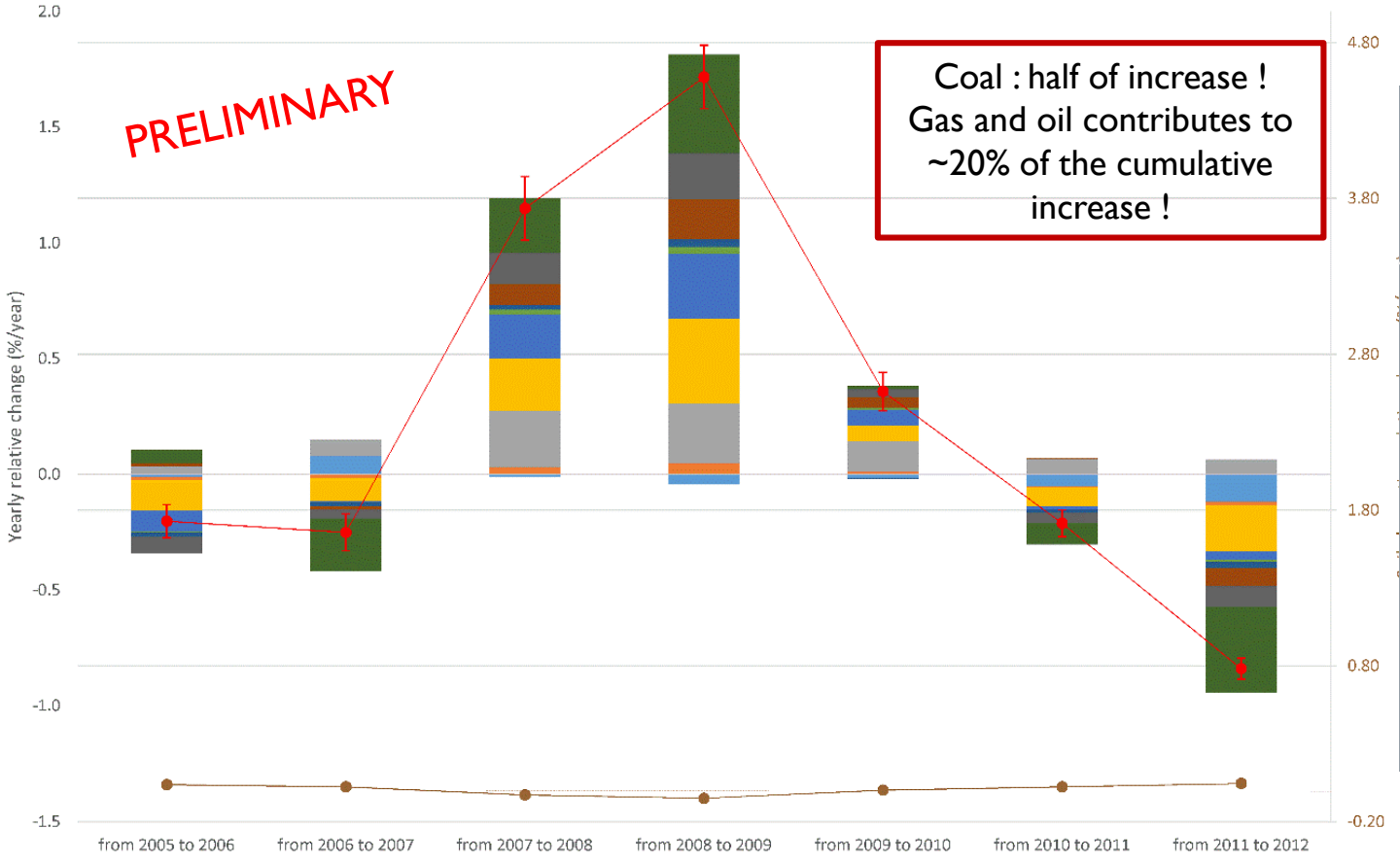
Coal mining contributes to 75% of the cumulative increase ! (only 7% of budget of CH_4)



Cumulative increase of CH_4 in % since 2005

	Total	1.14
1	Coal Mining	0.85
2	Gas and oil	0.41
3	Rice	0.29
4	Wetlands	0.27
5	Livestock	0.24
6	Waste	0.16
7	Other Anthr.	0.049
8	Biofuels	0.047
9	Other Natural	-0.017
10	Biomass Burning	-0.148
	sink Soil absorption	0.0541

GEOS-CHEM - Tracer Analysis
Tropospheric CH_4 - Tsukuba



Coal : half of increase !
Gas and oil contributes to ~20% of the cumulative increase !

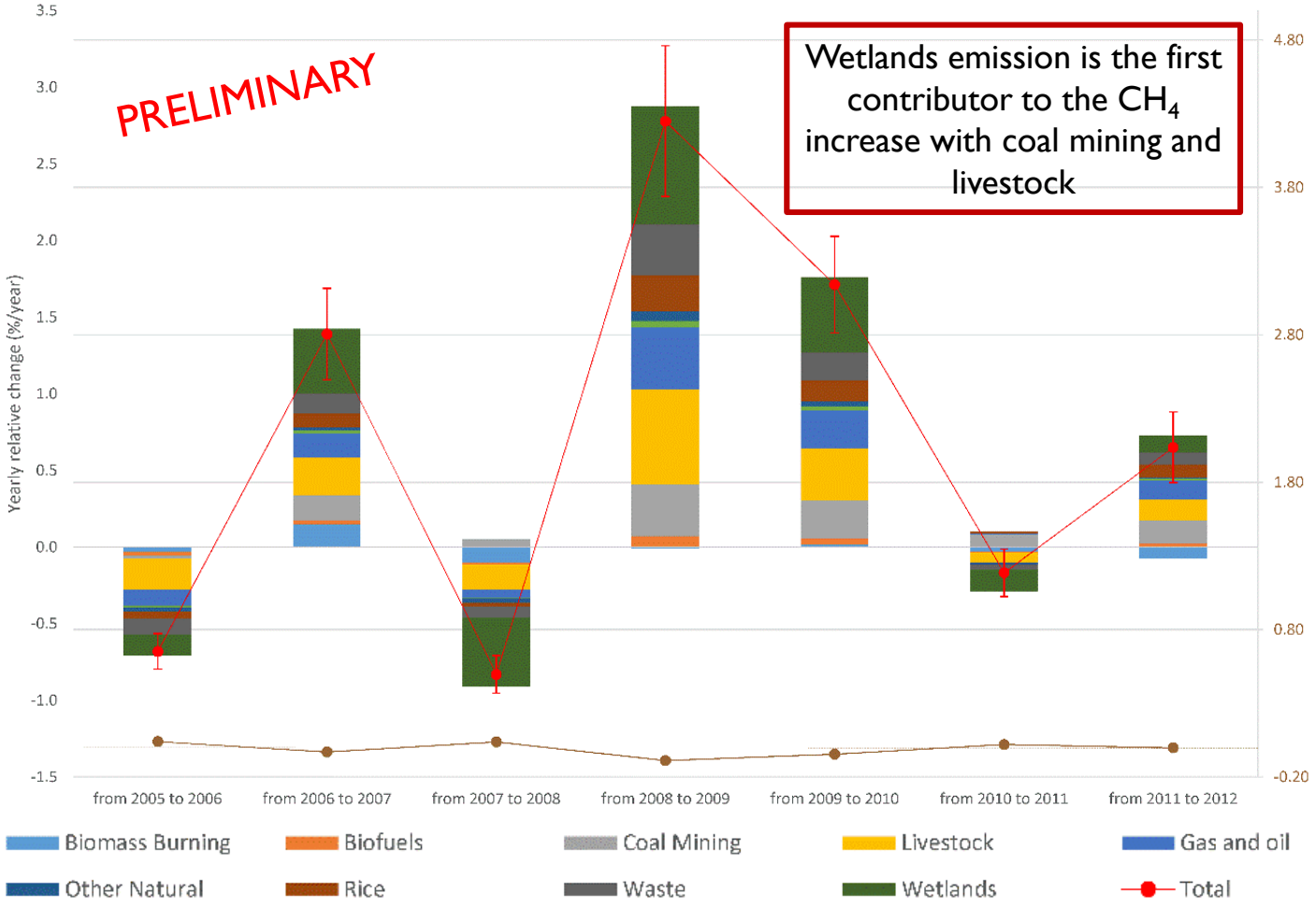
Cumulative increase of CH_4 in % since 2005

	Total	1.72
1	Coal Mining	0.86
2	Gas and oil	0.39
3	Rice	0.24
4	Livestock	0.15
5	Waste	0.13
6	Other Anthr.	0.044
7	Wetlands	0.043
8	Biofuels	0.038
9	Other Natural	-0.029
10	Biomass Burning	-0.170
sink	Soil absorption	0.059

GEOS-CHEM - Tracer Analysis
Tropospheric CH_4 - Lauder

PRELIMINARY

Wetlands emission is the first contributor to the CH_4 increase with coal mining and livestock



Cumulative increase of CH_4 in % since 2005

	Total	4.85
1	Wetlands	1.07
2	Coal Mining	1.02
3	Livestock	0.91
4	Gas and oil	0.77
5	Waste	0.51
6	Rice	0.49
7	Biofuels	0.12
8	Other Anthr.	0.089
9	Other Natural	0.050
10	Biomass Burning	-0.079
sink	Soil absorption	-0.061

Ranking of CH_4 tracers contribution to the increase
(from largest to smallest contribution)

PRELIMINARY

	Eureka	Jungfraujoch	Toronto	Tsukuba	Lauder	Arrival Heights
1	Coal Mining	Coal Mining	Coal Mining	Coal Mining	Wetlands	Wetlands
2	Wetlands	Gas and oil	Wetlands	Gas and oil	Coal Mining	Livestock
3	Gas and oil	Rice	Gas and oil	Rice	Livestock	Coal Mining
4	Livestock	Wetlands	Livestock	Livestock	Gas and oil	Gas and oil
5	Rice	Livestock	Rice	Waste	Waste	Waste
6	Waste	Waste	Waste	Other Anthr.	Rice	Rice
7	Biofuels	Other Anthr.	Biofuels	Wetlands	Biofuels	Biofuels
8	Other Anthr.	Biofuels	Other Anthr.	Biofuels	Other Anthr.	Other Anthr.
9	Other Nat.	Other Nat.	Other Nat.	Other Nat.	Other Nat.	Other Nat.
10	Biomass Burning	Biomass Burning	Biomass Burning	Biomass Burning	Biomass Burning	Biomass Burning

Conclusions & next steps…

- Comparisons between FTIR observations and GEOS-CHEM simulation shows a good agreement in terms of changes in CH_4 total column
- Vertical differences of CH_4 changes between FTIR observations and GEOS-CHEM simulation have been characterised
  - Stratospheric comparisons supported by ACE-FTS occultations
  - Tropospheric changes ≈ Total columns changes
- Preliminary tracer analysis shows a major contribution to the increase from coal mining and gas and oil exploitations

- Build CH_4 a priori profiles for each tracer in order to smooth the tagged simulation
- Site by site analysis of each tracer behaviour since 2005 and their contribution to the changes of methane

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